Joseph Thomas Toombs

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Summary

Mechanical engineer with over 8 years of research experience in advanced manufacturing, specializing in precision machine design, optomechanical systems and laser material processing for additive manufacturing, and optical metrology systems. Skilled learner eager to accept feedback and master new techniques to translate inventive ideas into practice. Able to independently drive key innovations as well as collaborate with cross-functional teams to maximize manufacturing productivity and product performance. Excited to transition from academia to industry to leverage broad technical expertise in a startup company that prizes creative engineering solutions to optimize advanced manufacturing processes.

Education

Ph.D. candidate, Mechanical Engineering **Expected May 2024**
Minors in MEMS/Nanofabrication and Optical Engineering
University of California, Berkeley, CA

B.S., Mechanical Engineering **May 2018**
University of Illinois, Urbana-Champaign, IL

Research Experience

UC Berkeley Dept. of Mechanical Engineering – Graduate Student Researcher **2018 – Present**
Design for Emerging and Nanoscale Manufacturing Lab – Hayden Taylor, Ph.D.

- Constructed optomechanical system with optical projection resolution of 4 µm for computed axial lithography (CAL) 3D printing of silica glass microstructures
- Measured improvement in silica glass strength consistency as printed with CAL vs DLP using Weibull statistics for fracture analysis. Led to collaboration with international industrial partner in glass-ceramics manufacturing.
- Collaborated with chemists and material scientists to optimize photochemistry using real-time FTIR spectroscopy. Demonstrated 10× reduction in minimum feature size compared to prior CAL system in the lab and 4× reduction compared to previously published data (see Toombs et al. 2022 *Science*)
- Designed laser-based optical projection system for novel roll-to-roll (R2R) microscale CAL with projection refresh and focus synchronized to roller servo motion and with control bandwidth of 100 Hz (see Toombs et al. 2021 *SPIE Adv. Lithography* and patent)
- Engineered solid-state photosensitive gel material to enable 3D printing of large arrays of microstructures on flexible substrates with R2R microscale CAL system (see Toombs et al. 2023 *Macromol. Rapid Comm.*)
- Fabricated pilot R2R web handling and slot-die coating subsystems to enable continuous printing of freeform polymer microstructures at web speeds of 6 cm/min
- Co-developed novel real-time tomographic refractive index optical metrology technique for observation of photopolymerization kinetics in resin-based 3D printing (see Li et al. 2020 *ACM Sym. Comp. Fab.* and patent). Led to discovery and quantification of previously hidden thermal and fluidic effects which hindered high print resolution
- Lead developer of VAM Toolbox, an open-source Python toolbox for generation of digital projections for volumetric 3D printing

UIUC Dept. of Mechanical Engineering – Undergraduate Research Assistant **2015 – 2018**
Nano-Micro Manufacturing Lab – Placid Ferreira, Ph.D.

- Developed a low-cost process for manufacturing laminated flexure-based composite micro machines
- Designed and constructed 3-axis parallel kinematics stage and quantified positional accuracy of 1 µm resolution in a 4 mm radius with optical metrology (see Correa et al. 2016 *J. Manuf. Processes*). Led to NAMRC Outstanding Paper in Manufacturing Processes award.
- Researched precision machine design for single-point diamond turning for micro lens applications involving work with aerostatic and hydrostatic linear and rotary actuators, flexure stages, and interferometers

Work Experience

NASA Marshall Space Flight Center — Research Associate **Summer 2017**

- Designed and developed a test bed for soldering investigations in microgravity on interdisciplinary team of 4 interns (see Daly et al. 2017 *Gravitational and Space Research*). Foundational research led to subsequent studies on the International Space Station by NASA scientists with later iterations of the platform

Leadership and Teamwork

UC Berkeley Dept. of Mechanical Engineering

- Communicated student project feedback and organizational goals between students and center leadership and fostered interinstitutional collaborations as the UC Berkeley student representative in the NSF NASCENT ERC (UT Austin, Texas) for scalable nanomanufacturing
- Led team of 2 undergraduate and 2 early-stage graduate students in the design and manufacturing phase of an automated parallelized CAL 3D printer which produced >100 polymer cm-scale parts in 10 minutes of microgravity

NSF National I-Corps program — Technical Lead **Summer 2023**

- Interviewed >100 dentists and lab technicians about dental restoration manufacturing needs to evaluate product-market fit of microscale CAL printing of custom teeth crowns
- Concluded further R&D was needed but gained valuable entrepreneurial experience understanding customer pain points and an appreciation of business model development supported by evidence gleaned from customer discovery

Technical Skills

Prototyping	Zemax Optic Studio | Optical systems design and assembly | Autodesk Inventor | Solidworks | Creo Parametric | FEA | Manual lathe/mill | CNC | Wire EDM | Polyjet/DLP/FDM 3D printing
Programming	Python (Numpy, OpenCV, SciPy, PyTorch, Matplotlib) | Matlab | C++ | Tomographic reconstruction
Metrology	Interferometry | Confocal microscopy | Electron microscopy | 3D laser scanning
Material Characterization	Rheology | Tension/compression/flexural mechanical testing | FTIR | UV-Vis spectroscopy | EDS
Other Skills	Laser material processing | Motion control | Flexural mechanisms design | Photolithography mask design | Microfluidics

Grants/Awards

NSF Innovation Corps Teams Program
Hayden Taylor, Nour Akiki, and Joseph Toombs. (2023). Micro-scale computed axial lithography for 3D fabrication in challenging materials. $50,000

NASA Technology Advancement Utilizing Suborbital Flight Opportunities
Hayden Taylor and Joseph Toombs. (2021). Evaluation of Computed Axial Lithography for rapid, volumetric additive manufacturing under low-gravity conditions. $400,000

Patents

Roll-to-roll based 3d printing through computed axial lithography. Patent: WO2022178426. Link

High fidelity 3d printing through computed axial lithography. Patent: WO2023081404. Link

Computed axial lithography optimization system. Patent: WO2022015657. Link

Publications

Joseph Toombs, Chi Chung Li, Hayden Taylor. (2024). Roll-to-roll tomographic volumetric additive manufacturing for continuous production of microstructures on long flexible substrates. In *SPIE OPTO: Advanced Fabrication Technologies for Micro/Nano Optics and Photonics XVII.*

Chi Chung Li, **Joseph Toombs,** Hayden K. Taylor, Thomas J. Wallin. (2023). Tomographic projection optimization for volumetric additive manufacturing with general band constraint Lp-norm minimization. Arxiv (2023). Link

Quinten Thijssen*, **Joseph Toombs***, Hayden K. Taylor, Sandra Van Vlierberghe. (2023). From pixels to voxels: A mechanistic perspective on volumetric 3D-printing. *Progress in Polymer Science* 147. Link

Jorge Madrid-Wolff, **Joseph Toombs**, Riccardo Rizzo, et. al. (2023). A review of materials used in tomographic volumetric additive manufacturing. *MRS Communications* 13. Link

Joseph T. Toombs, Ingrid K. Shan, Hayden K. Taylor. (2023). Ethyl Cellulose-Based Thermoreversible Organogel Photoresist for Sedimentation-Free Volumetric Additive Manufacturing. *Macromolecular Rapid Communications* 44. Link

Quinten Thijssen, Astrid Quaak, **Joseph Toombs**, Elly De Vlieghere, Laurens Parmentier, Hayden Taylor, Sandra Van Vlierberghe. (2023). Volumetric Printing of Thiol-Ene Photo-Cross-Linkable Poly(ϵ-caprolactone): a Tunable Material Platform serving Biomedical Applications. *Advanced Materials*. Link

Joseph T. Toombs, Manuel Luitz, Caitlyn C. Cook, Sophie Jenne, Chi Chung Li, Bastian E. Rapp, Frederik Kotz-Helmer, and Hayden K. Taylor. (2022). Volumetric Additive Manufacturing of Silica Glass with Microscale Computed Axial Lithography. *Science* 376. Link

Charles M. Rackson, **Joseph T. Toombs,** Martin P. De Beer, Caitlyn C. Cook, Maxim Shusteff, Hayden K. Taylor, and Robert R. McLeod. (2022). Latent Image Volumetric Additive Manufacturing. *Optics Letters* 47. Link

Chi Chung Li, **Joseph Toombs,** Sui Man Luk, Martin De Beer, Johanna Schwartz, Maxim Shusteff, and Hayden Taylor. (2022). Computation optimization and the role of optical metrology in tomographic additive manufacturing. In *SPIE LASE: Advanced Fabrication Technologies for Micro/Nano Optics and Photonics 2022*. Best paper award. Link

Joseph Toombs, Chi Chung Li, Hayden Taylor. (2021). Design of a Tomographic Projection Lithography System and Material for Roll-to-Roll Fabrication of 3D Microstructures. In *Proceedings of the 2021 International Conference on Micro- and Nano-devices Enabled by R2R Manufacturing*.

Joseph Toombs and Hayden K. Taylor. (2021). Design of a tomographic projection lithography process for roll-to-roll fabrication of 3D microstructures. In *SPIE Advanced Lithography: Novel Patterning Technologies 2021*. Link

Indrasen Bhattacharya*, **Joseph Toombs***, and Hayden Taylor. (2021). High fidelity volumetric additive manufacturing. *Additive Manufacturing* 47. Link

William S. Harley, Chi Chung Li, **Joseph Toombs**, Cathal D. O'Connell, Hayden K. Taylor, Daniel E. Heath, and David J. Collins. (2021). Advances in biofabrication techniques towards functional bioprinted heterogeneous engineered tissues: a comprehensive review. *Bioprinting* 23. Link

Charles M. Rackson, Kyle M. Champley, **Joseph T. Toombs**, Erika J. Fong, Vishal Bansal, Hayden K. Taylor, Maxim Shusteff, and Robert R. McLeod. (2021). Object-space optimization of tomographic reconstructions for additive manufacturing. *Additive Manufacturing* 48. Link

Kevin Coulson, **Joseph Toombs**, Magnus Gu, and Hayden Taylor. (2021). Adaptive voxelization for rapid projection generation in computed axial lithography. In *Solid Freeform Fabrication 2021: Proceedings of the 32nd Annual International*, Austin, Texas. Link

Chi Chung Li, **Joseph Toombs**, and Hayden Taylor. (2020). Tomographic color Schlieren refractive index mapping for computed axial lithography. In *Proceedings - SCF 2020: ACM Symposium on Computational Fabrication*. Link

Shannen Daly, Micah Hardyman, James Ragan, **Joseph Toombs**, Tracie Prater, and Richard N. Grugel. (2017). MMaJIC, an Experimental Chamber for Investigating Soldering and Brazing in Microgravity. *Gravitational and Space Research* 5, 2. Link

Jorge E. Correa, **Joseph Toombs**, Nicholas Toombs, and Placid M. Ferreira. (2016). Laminated micro-machine: Design and fabrication of a flexure-based Delta robot. *Journal of Manufacturing Processes* 24. NAMRC | SME: Outstanding Paper in Manufacturing Processes. Link

* indicates equal contribution

Conference Presentations

Joseph Toombs, Chi Chung Li, Hayden Taylor. (2024). Roll-to-roll tomographic volumetric additive manufacturing for continuous production of microstructures on long flexible substrates. In *SPIE OPTO: Advanced Fabrication Technologies for Micro/Nano Optics and Photonics XVII*

Joseph Toombs, Chi Chung Li, Hayden Taylor. (2021). Design of a Tomographic Projection Lithography System and Material for Roll-to-Roll Fabrication of 3D Microstructures. In *2021 International Conference on Micro- and Nano-devices Enabled by R2R Manufacturing*.

Hayden Taylor, **Joseph Toombs,** Chi Chung Li, Sui Man Luk, Weisa Wang, Ingrid Shan, Vishal Bansal, and Alexander Watson. (2021). Emergence of Multi-Material Volumetric Additive Manufacturing—Overprinting and Particle Inclusion. In *MRS SF02: Additive Manufacturing–From Material Design to Emerging Applications.*

Hayden K. Taylor, **Joseph Toombs**, Sui Man Luk, Samira Feili, Hossein Heidari, Chi Chung Li, Vishal Bansal, Kevin Coulson, and Elyas Goli. (2021). Modeling of light propagation in computed axial lithography with photopolymers. In *SPIE OPTO: Emerging Digital Micromirror Device Based Systems and Applications XIII*.